DOCUMENT RESUME

ED 181 306 CE 023 912

AUTHOR Bailey, Jon S.: Hughes, Ronald G.
TITLE Applied Behavior Analysis in Flying Training Research. Interim Report for Period June 1978-August 1978.
INSTITUTION Air Force Human Resources Lab., Williams AFB, Ariz. Flying Training Div.
SPONS AGENCY Air Force Human Resources Lab., Brooks AFB, Texas.
REPORT NO AFHRL-TR-79-38
PUB DATE Jan 80
NOTE 18p.; Not available in paper copy due to small print

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Behavioral Science Research; *Behavior Theories; *Flight Training; Learning Processes; *Learning Theories; *Military Training; *Simulators; *Teaching Methods
IDENTIFIERS Air Force; United States

ABSTRACT

Research developments in learning theory over the past fifty years have led to principles of behavior which have been shown in innumerable applied settings to be valuable in analyzing and modifying human behavior. When applied to flying training using simulators, these principles suggest that a significant contribution could be made in improving the way in which instructor pilots teach new students via more effective use of simulator functions. In addition, flying skills could probably be acquired more readily if tasks were presented in a more systematic manner, taking the principles of learning into account. When the simulator is conceptualized as merely an inferior copy of an aircraft, its potential as a teaching device (perhaps superior to the actual plan, in this regard) is likely to be overlooked. Thus, a behavioral analysis of optimal conditions of learning would make a major contribution to both the design and use of current and future flight simulators. (This report describes the basic principles of behavior and attempts to relate them to the task of improving flying training.) (Author/BM)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

CE

AFHRL-TR-79-38

AIR FORCE

HUMAN RESOURCES

LABORATORY

ED181306

APPLIED BEHAVIOR ANALYSIS IN FLYING TRAINING RESEARCH

By

Jon S. Bailey
Department of Psychology
The Florida State University
Tallahassee, Florida 32306

Ronald G. Hughes

FLYING TRAINING DIVISION
Williams Air Force Base, Arizona 85224

January 1980
Interim Report for Period June 1978 – August 1978

Approved for public release; distribution unlimited.

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

ED023912

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

2

NOTICE

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This interim report was submitted by Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123 with HQ Air Force Human Resources Laboratory, Brooks Air Force Base, Texas 78235. Dr. Ronald G. Hughes (FTR) was the Principal Investigator for the Laboratory.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

DIRK C. PRATHER, Lieutenant Colonel, USAF
Technical Advisor, Flying Training Division

RONALD W. TERRY, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TR-79-38	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) APPLIED BEHAVIOR ANALYSIS IN FLYING TRAINING RESEARCH		5. TYPE OF REPORT & PERIOD COVERED Interim June 1978 – August 1978
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jon S. Bailey Ronald G. Hughes		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Flying Training Division Air Force Human Resources Laboratory Williams Air Force Base, Arizona 85224		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62205F 11230234
11. CONTROLLING OFFICE NAME AND ADDRESS HQ Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE January 1980
		13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

application of training technology
behavioral analysis
flying training
pilot training
simulation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Research developments in learning theory over the past 50 years have led to principles of behavior which have been shown in innumerable applied settings to be valuable in analyzing and modifying human behavior. When applied to flying training using simulators, these principles suggest that a significant contribution could be made in improving the way in which Instructor Pilots teach new students via more effective use of simulator functions. In addition, flying skills could probably be acquired more readily if tasks were presented in a more systematic manner, taking the principles of learning into account. When the simulator is conceptualized as merely an inferior copy of an aircraft, its potential as a teaching device (perhaps superior to the actual plane, in this regard) is likely to be overlooked. Thus, a behavioral analysis of optimal conditions of learning would make a major contribution to both

DD FORM 1 JAN 73 1473

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MAR 0 4 1980

Item 20 Continued:

the design and use of current and future flight simulators. In this report, an attempt is made to elucidate the basic principles of behavior and to relate them to the task of improving flying training.

PREFACE

This technical report was prepared during Dr. Bailey's participation in the 1978 USAF-ASEE Summer Faculty Research Program, sponsored by the Air Force Office of Scientific Research. This report was prepared under Work Unit 11230234, Advanced Instructional Features and Methods in ASPT. The work unit supports Project 1123, Flying Training Development, Task 02, Instructional Innovations in Flying Training. This effort further supports Air Force Human Resources Laboratory Technical Planning Objective G03, Specific Goal 2, Training Methods and Media.

TABLE OF CONTENTS

	Page
I. Introduction	5
II. Applied Behavior Analysis	5
III. Basic Principles of Behavior	5
IV. Flying Training and Simulators	9
V. The Design of Simulators	9
VI. Behavioral/Task Analysis of Flying Training: A New Model for Simulator Design	10
VII. Application of the Model: A Preview	11
VIII. Conclusions and Recommendations	12
References	13

LIST OF ILLUSTRATIONS

Figure		Page
1	Backward chaining of 30° dive bomb task	8

APPLIED BEHAVIOR ANALYSIS IN FLYING TRAINING RESEARCH

I. INTRODUCTION

Psychology has emerged in the last few decades as the science of human behavior with not only a well founded theoretical base (Skinner, 1953, 1969) but also with a reliable technology (Ayllon & Azrin, 1968; Bandura, 1969; Risley, 1970) capable of making significant contributions to the culture. This technology of behavior change appears well-suited to applied problems such as flying training since it is predicated on an analysis of behavior which considers learning to be a significant factor. A cohesive theory or model of learning in flying training and a technology capable of improving the acquisition of flying skills would appear to be a natural outcome as sophisticated behavioral techniques are applied to an important applied problem. When the acquisition of flying skills occurs largely at 15,000 feet, the process may be difficult to observe and therefore analyze; but the advent of flight simulators, where conditions of learning can be not only observed but also manipulated directly, now permits experimental research on the learning process to take place. This merging of behavioral psychology and problems of flying training represents an exciting new area of applied research which should benefit both areas.

II. APPLIED BEHAVIOR ANALYSIS

One fairly recent spinoff of 50 years of research in learning theory has been a field of psychology in which basic principles of behavior derived from the laboratory are applied to problems of human behavior (Baer, Risley, & Wolf, 1968; Kazdin, 1978). Termed "Applied Behavior Analysis," this field has made significant contributions to rehabilitation, mental retardation, clincal psychology, delinquency, community psychology, and a variety of related human service specialties (Kazdin, 1975). The contributions have been made possible by advances in conceptual and methodological spheres and have allowed for the emergence of a technology of behavior change (often referred to as behavior modification) which promotes improvements in human learning through an analysis of the contingencies surrounding a person's actions (Skinner, 1953, 1968, 1969). Deficits in behavior are often found to be due to inadequate antecedents to prompt behavior, lack of reinforcement for behavior which does occur, or for a variety of interrelated reasons traceable to an environment incapable of supporting the desired behavior (Bailey, in press; Martin & Pear, 1978).

While the most obvious examples of the contribution of applied behavior analysis may be seen in clinically related fields, advances in the analysis of the educational process have also been made (Keller, 1968; Miller & Weaver, 1976; Skinner, 1968). Here, the approach has brought the principles of behavior to bear on the problems of understanding what is necessary to establish and maintain new repertoires. (This approach has much in common with concurrent developments in instructional technology but appears to have evolved independently.) With the precedent set for the applicability of behavior analysis to so many varied educational areas (ranging from pre-schools to elementary classrooms to college instruction), the extension to an analysis of flying training seems predictable.

III. BASIC PRINCIPLES OF BEHAVIOR

The basic principles of behavior presented here represent the results of many years of basic and applied research. (The interested reader is referred to the *Journal of the Experimental Analysis*

of Behavior and the *Journal of Applied Behavior Analysis* for primary sources of this research.) As mentioned earlier, most of the applied work has been carried out in health or education related areas (e.g., Bostow & Bailey, 1969; Iwata, Bailey, Brown, Foshee, & Alpern, 1976; Johnson & Bailey, 1974), and little direct work in military training is available for citation. For purposes of exposition, an attempt will be made to relate each of the basic principles to the topic of flying training.

Reinforcement. Perhaps the most widely recognized principle in the behavioral framework is that of reinforcement. This principle stresses the importance of the consequences of behavior, in particular positive consequences which follow (i.e., are contingent upon) a certain action or response and which strengthen or make the behavior more likely. In flying training, such consequences are already well institutionalized and may be seen in the form of grades of exams, verbal feedback from an Instructor Pilot (IP) on flying proficiency or, ultimately, promotion for superior performance. The purpose of a good officer efficiency report is to strengthen the behavior leading up to it. (The function of a negative evaluation as a punisher will be described in the next section.) There is little doubt that learning of almost any kind can be improved through the increased use of reinforcement for desirable behavior.

Two clear cases in flying training appear relevant here. Since so much of the instruction of the undergraduate pilot is carried out in a one-to-one setting with the IP, the opportunity for increased reinforcement for correct behavior in the form of social approval is obvious. Informal observations of IP-student interactions reveal a dearth of positive feedback. While the research has not been carried out with this subject population (Broden, Bruce, Mitchell, Carter, & Hall, 1970; Copeland, Brown, & Hall, 1974; Hall, Lund, & Jackson, 1968), the implications seem obvious. Increased use of approval statements of a positive type (e.g., "Hey, that's great." "Very nice maneuver." "Nicely executed.") are bound to improve not only learning, but also morale. Since most IPs appear disinclined naturally to be a wellspring of positive feedback, training to improve this form of communication with students may need to be added to Pilot Instructor Training.

A second example of the use of reinforcement can be seen in the way the simulators are used in teaching. An experienced pilot can readily tell from the instruments and the view from the cockpit when a maneuver has been completed successfully; much like an experienced pianist can tell when a piece has been played well. For the novice, such automatic feedback is absent, and for rapid learning to take place, it needs to be supplemented in the early stages of learning. The addition of counters, tones, or other stimuli which could be used to confirm correct performance could easily be added to the simulated cockpit. With the development of automated performance measurement (Waag, Eddowes, Fuller, & Fuller, 1975), the feasibility of having the computer continuously monitor and score a student's flying skill seems apparent.

Punishment. Any time a consequence is designed to follow a given bit of behavior such that the strength or probability of the behavior occurring in the future is reduced, the process is referred to as punishment. Since there may well be numerous side effects (Azrin & Holz, 1966) of using punishment (e.g., anxiety and fear may increase, student may associate learning of the task with aversiveness, or student may learn to avoid the source of the punisher), the use of this procedure is not commonly recommended in educational settings (Skinner, 1968). However, in flying training, the student may need to be made very aware of the natural punisher for poor attention to the details of flying, viz, crashing. Thus, most simulators are designed to provide this feedback to students. To be most effective, simulators could probably be designed to give negative feedback early enough to allow the student to correct any error. A "freeze" function currently exists on Instrument Flight Simulators. In one sense, this function resembles the use of "Time-out from positive reinforcement" (usually referred to simply as T.O.) in the clinical literature (Bostow & Bailey, 1969). If flying the simulator is a reinforcing activity, then being in T.O. for a short time upon erring in a flying task may well be an effective punisher that could be used more widely. (Note: This author could find no published reports on the effects of the freeze function in flying training, thus this analysis should be considered tentative until such applied research has been carried out.)

In advanced instruction, such as in air-to-air or air-to-ground combat, it may be worthwhile to add feedback of a more realistic, but no doubt aversive nature. Failure to "check six" could be programmed to result in a malfunction that would simulate the plane's being hit with enemy fire, for example.

Shaping and Chaining. Most good instructors know that to keep their students interested, challenged, and involved in the task at hand, they need to continually raise the criterion for a good performance. In behavior theory, this is known as "shaping" (Kazdin, 1975) and as with the latter two principles, examples for usage with IPs and in adaptive simulators may be easily seen. Expecting an undergraduate pilot to complete an instrument approach correctly on the first try may well be setting the standard too high. In reinforcing *approximations* to the final performance, the good IP will no doubt have a student reach the final criterion more quickly. As the student progresses, the criterion can be raised so that only progressive improvement in performance rates an approval.

Simulators could be computer programmed so as to present tasks to students so that they would gradually take on an increasing number of the piloting functions. In taking off, for example, the student might initially only have to control the throttle but on successive takeoffs might be required to manipulate the stick to control pitch. Later, the student would also be required to adjust the trim of the elevators, retract the flaps, and so on. When a perfect takeoff could be executed, the student would be required to cope with gradually more difficult crosswinds and various emergency conditions. Programming a simulator to require a progressive increase in behavior does not seem at all unfeasible and would probably greatly reduce the time required to master many skills.

Many behaviors in flying consist of *sequences* of responses, where early responses must occur in a certain order (e.g., the overhead pattern) so that the final outcome (i.e., a safe landing) can be achieved. Analyzed behaviorally, it can be seen that only the last member of a chain is actually reinforced. This means that early members of the chain will usually not be learned very readily, and their slow acquisition may well retard the development of the rest of the chain of behavior. The most direct solution, which is readily arranged in a simulator, is to have the task designed so that only the last member of the chain must be carried out to achieve the reinforcer. With the 30° dive bomb task, a pilot can first be positioned so as to fly the final. When this is mastered, the roll-in is added and so on until the whole task is completed (see Figure 1).

Prompting and Fading. In the initial stages of learning, new behaviors are weak and may not readily occur when they should. At these times, it may be advisable to add stimuli to help initiate a response – such events are called prompts (e.g., Van Houten & Sullivan, 1975). As a general rule, once a behavior begins to occur regularly when the prompt is given, the prompt will be faded. This use of extra stimuli to cue behavior that can stand alone under naturally occurring environmental stimuli seems readily applicable to flying training. For example, in the overhead pattern, the student must know when to put the speed brakes down, when to extend the landing gear, and when to lower the flaps. A simulator could easily be adapted to cue these responses at the proper time, and when they are occurring appropriately, the cues could be faded. Similar usage of prompting and fading cues could be combined with shaping (as in training the takeoff) to provide a powerful combination of behavioral techniques to guarantee the rapid acquisition of complex tasks.

Discrimination and Stimulus Control. It is most desirable for pilots to constantly respond to their environment so that they can make the necessary adjustments to keep their plane safely aloft. A pilot who responds appropriately to changes in the environment is said to be under stimulus control, and this form of responding is clearly a goal of flying training. The student pilot must learn to discriminate the various wind conditions and to develop appropriate responses to them. For example, stimulus control is gained as the student has repeated exposure to instances of the stimuli involved, and these are readily programmed in a simulator. Learning to cope with an

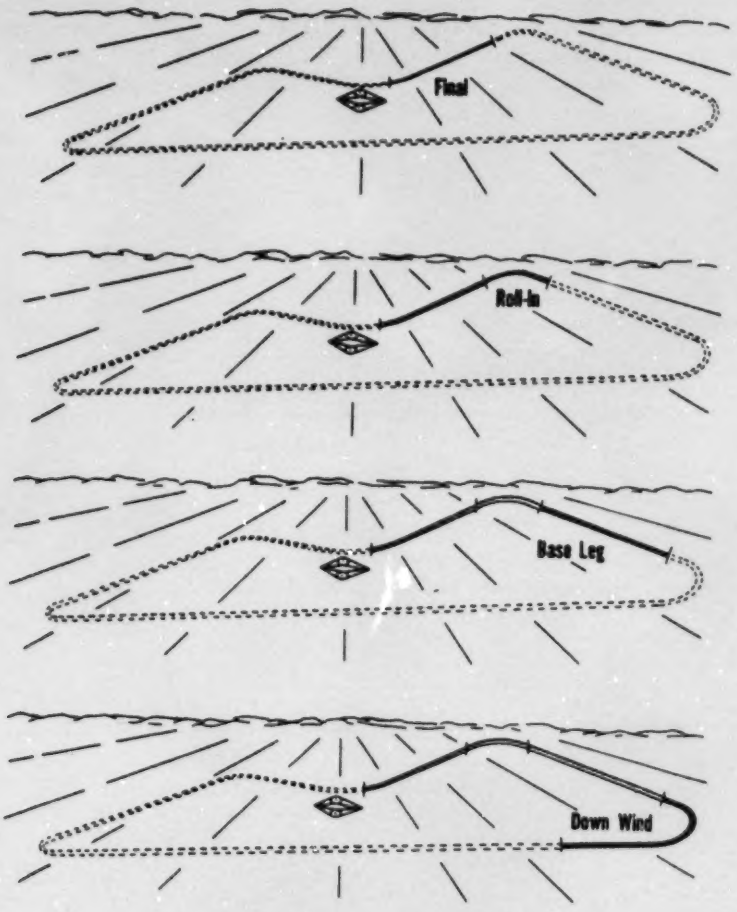

Figure 1. **Backward chaining of 30° dive bomb task.**

engine failure is safely achieved in a simulator, and clearly, a student who has had several instances in which to detect this malfunction will be better able to respone in an emergency. Students also need to detect changes in wind direction and visibility and to take the necessary action. Both conditions can be programmed in a simulator and very fine discriminations if both could be taught using systematic stimulus presentation techniques.

Stimulus control is also important in advanced training when a pilot must spot a target quickly and respond appropriately. Repeatedly confronting the pilot with a variety of targets and gradually requiring shorter and shorter reaction times could improve the acquisition of complex maneuvers, such as the pop-up which is employed in air-to-ground combat. Arranging for simulation of enemy aircraft to occasionally appear while pilots are flying formation should also aid in the development of good visual discrimination.

Generalization. Once a behavior has been strengthened in one environment there is a likelihood that it will occur in similar environments; the more similar the environment, the more likely the behavior is to occur. It is, of course, this form of *stimulus generalization* that has motivated engineers to make the simulator as much like the plane as possible. It is important to note that in human factors work, when the goal of stimulus generalization is sought, the effects

of increased similarity between the simulator and the aircraft must be measured by looking at changes in behavior, and the costs of increased fidelity must be weighed against the benefits. Adding motion, for example, to a simulator with a wraparound visual field may not actually enhance performance in the target aircraft (Martin & Waag, 1978) and furthermore, the sophisticated hydraulic systems necessary for motion are costly. Research to discover how much visual field may be required to allow a simulator to be used in certain maneuvers, such as carrier landings (Perry, 1978), also demonstrates the importance of stimulus generalization in flying training.

When a response is strengthened and this then increases the probability of similar responses occurring, responses generalization has been said to have taken place. Learning a certain sequence of behaviors verbally (e.g., takeoff procedures) should lead to their actually being performed at a later time. Practicing visual-motor tracking tasks could increase the ability to make the fine adjustments in the stick necessary to maintain proper attitude. Indeed, mentally rehearsing a certain maneuver (Prather, 1978) may well improve the performance of critical flying skills.

IV. FLYING TRAINING AND SIMULATORS

Learning to fly an aircraft is unique in that inadequate preparation for the task can lead to more than a failing grade. It is perhaps the literal life or death nature of the consequences that has led, and rightly so, to conservative strategies for training. Rather than risk less than perfect transfer of training, the aircraft itself has been preferred over the use of modern day simulators for teaching flying skills. However, economic contingencies and fuel shortages have become translated into a guideline from the Office of Management and Budget to reduce flying hours by 25% by 1981 (Committee on the Armed Services, 1976). Presumably, the only reasonable way to meet this goal and still maintain high standards of safety is to employ simulators whenever possible in the training process. Simulators have come a long way since the pioneering work of Ed Link on his "pilot maker" in 1929. The development of the full-mission simulator that is capable, potentially, of almost exactly duplicating every feature of an operational aircraft has been recent indeed (Hagin & Smith, 1974). While engineering technology and computer science have made great strides in providing for fidelity of visual (Nass, Seats, & Albery, 1975), motion (Kron, 1975a), and handling characteristics (Kron, 1975b), few advances in exploring the use of a modern day simulator as an ideal teaching device have been made (Caro, 1977a). In the hands of an experienced pilot, there is a natural tendency to use a simulator much like the aircraft would be used, thus overlooking the fact that the aircraft itself is certainly a less than perfect setting for maximizing the acquisition of skills required to fly a plane. Safety requires the IP to put proper maneuvering above analyzing the instructional process and the stress involved in correcting student errors may result in less than optimal forms of feedback. Since the cockpit is operational and the instruments require constant monitoring to maintain proper attitude, the student may be easily overloaded with information in the early stages on instruction and be unable to progress as systematically as would be desirable. No opportunity to practice a particular part of a maneuver in the aircraft is feasible, even though it would perhaps be most desirable from a learning point of view.

V. THE DESIGN OF SIMULATORS

Historically, engineers and pilots have been principally responsbile for the design of simulators, and it should come as no surprise that fidelity to imitate the aircraft has been the primary goal of the development effort (Caro, 1977b). Any notion that psychological fidelity is the real goal has been ignored, and the proposition that simulators should be designed primarily as training devices is virtually unheard of in simulator design circles (Caro, 1977b).

Current advanced simulators are equipped with certain training "features" that are presumed to facilitate the acquisition of flying skills (Hughes, 1978, 1979; Isley & Miller, 1976). In some cases, the features are simple hardware applications (programmed malfunctions, hard copy printout); in others, these features merely mimic what an instructor might do (automatic briefing, checkride, and demonstration). Only a few of the features would appear to approach the potential of a sophisticated record/playback or of adaptive training, and in no case have the features been adequately evaluated (Isley & Miller, 1976). Even their limited usage is based upon an unvalidated model of behavior change. This practice of designing simulator "training" features on the model of the instructor has, no doubt, severely retarded the development of a model of flying training. An alternative model would emphasize the skills to be acquired and suggest more effective ways of training based upon a task analysis. From this model should flow implications for the training features and procedures and research to evaluate them prior to their incorporation in the training syllabus or installation in future training simulators.

The lack of appreciation for the role of the simulator as a teaching device is understandable in light of the relatively recent emergence of a behaviorally based technology of teaching and the fact that psychologists specializing in the learning process have not been involved in the design phase of simulator development. This oversight, upon investigation, is directly traceable to the conspicuous absence of any substantial body of knowledge demonstrating how the principles of learning can be used to improve simulator deployment. How the significant body of relevant research in applied behavior analysis could have escaped the attention of those involved in simulator research is difficult to explain. The need for correction of this glaring deficit is greater than can be met in one paper, but a start needs to be made.

VI. BEHAVIORAL/TASK ANALYSIS OF FLYING TRAINING: A NEW MODEL FOR SIMULATOR DESIGN

Any task which can be readily observed can be analyzed behaviorally. Flying a sophisticated jet aircraft, although admittedly a difficult task, is not different in principle from carrying out any other complex sequence of behaviors. Viewed in the abstract, it may be seen as a set of rapid, continuous, fine-motor responses to a multiplicity of visual and proprioceptive cues from both inside and outside the aircraft. What makes the task unusual is that decisions and responses must be made so rapidly and flawlessly, since either a delayed response or an incorrect judgment could be fatal. It is this latter element, no doubt, that puts such stress on the pilot and which probably makes acquisition of the motor skills in the aircraft itself so labile.

A behavioral analysis of flying, then, would begin with a micro analysis of the tasks to be acquired (Meyer, Laveson, Weissman, & Eddowes, 1974) and would then proceed to determine how each task could be simplified for purpose of instruction. This general approach is already used in so-called "part task" trainers, such as the T-4, where students learn to respond to the instrument panel before they spend any time in the actual aircraft. The Air Force has also recognized the contribution of cognitive pretraining in facilitating the acquisition of flying skills (Smith, Waters, & Edwards, 1975) which is clearly a method of simplifying a task by presenting certain of the materials in a different format and in a different point in time from the rest of the task. With simplification of the task as the goal for any behavioral analysis, one may begin to ask how a task can be broken down.

Component Analysis. One way of analyzing a complex task is to look at the components which make up the whole task and to determine how they can be taught more efficiently (Meyer et al., 1974). Landing a plane, for example, requires that the student be able to fly straight-and-level, do steep turns, fly a gradual descent, all the while keeping the airspeed properly adjusted, correcting for crosswinds, and so on. (In the operational aircraft, these behaviors must be performed concurrently, whereas in the simulator they could theoretically be presented as separate tasks and then later be required as more and more complex concurrent operants.)

Chain or Sequence Analysis. Another way of analyzing a flying task is to view it as a chain of behavior. In this conceptualization, the pilot must execute a sequence of behaviors in a certain order (the overhead pattern is also an excellent example of this). With long chains, acquisition of the task is frequently difficult because the early member or components of the chain are so far removed from the reinforcer. Such chains of behavior can be simplified, and therefore presumably taught more efficiently, if they are presented in a backward sequence.

Dimension of Difficulty Analysis. Still another way to analyze a difficult task is to determine the dimensions which are responsible for making it difficult. Some skills may be hard to acquire because they require too rapid motor responses (time dimension). In such cases, a capability for performing a task (e.g., strafing or formation flying) initially in slow motion might allow the student to master the motor skills first and then be required to perform the task at faster and faster speed until normal operational velocities are reached. (It should be clear that a simulator is the only feasible device for such training to take place and that such a use of the simulator represents a potentially important feature which is independent of the fidelity of its motion or visual system.)

Size becomes an important dimension when one considers tasks such as bombing or strafing where a larger or more salient target is easier to hit initially. Thus, the simulated visual scene could be programmed to have large targets readily discernible from the background. These targets would be used early in a bombing training task, and as the student gained proficiency, the targets could be automatically made smaller and more difficult to spot. Presumably a similar strategy could be used in simplifying any task that requires a motor response to some small segment of the visual environment (e.g., aerial delivery of cargo or in-flight refueling).

Augmented Feedback. Still another way to simplify a task for purposes of instruction is to determine if judgmental aids might be developed to improve performance. Such aids can be used to enhance a feature of the environment, such as height and distance from the runway, as with visual approach slope indicator (VASI) that permits a more rapid acquisition of landing. A similar device for carrier landings (the so-called "meatball") and another aid for improving bombing (Hughes, Paulsen, Brooks, & Jones, 1978) illustrate the notion of providing additional cues to pilots to improve performance.

Summary of Behavioral/Task Analysis Model. This brief introduction to the behavioral/task analysis model should serve as a clear contrast to the current deployment of simulators. Designing a simulator around a model of an instructor pilot who feels most comfortable teaching in an actual plane is destined to be replaced with a model based on an analysis of the tasks to be taught. A sophisticated behavior/task analysis employing research which shows how tasks can be broken into components, the components ordered sequentially, and the dimensions of difficulty adjusted so that acquisition of a skill proceeds smoothly and quickly seems in keeping with the current state-of-the-art in computer-generated visual systems and other recent engineering developments.

VII. APPLICATION OF THE MODEL: A PREVIEW

To illustrate the application of the behavioral/task analysis model, a hypothetical case will be given. Learning to land an aircraft is clearly one of the most difficult tasks for a new pilot to master (Eddowes & King, 1975) and provides an excellent example of how the model might be employed.

The overhead pattern is a ready example of a chain of behaviors consisting of the initial approach, downwind leg, final turn, and final approach. The model would suggest that training on the last segment would be most fruitful. The first, step would be to determine the behavioral

components of the final apprach and would use cognitive pretraining where feasible to prepare the student for each component. The student must be able to adjust the speed brakes, control pitch attitude, and adjust the throttles, for example, in the roundout phase of the final approach. The simulator would be programmed to require that the student take responsibility for each of these concurrent behaviors in some specific order. Similarly, the components of the touchdown and the landing roll would be presented to the student in a graduated manner. When all of the components had been acquired, the simulator would be positioned "on final" and the student required to complete this portion of the overhead pattern to criterion. (The training to this point would be highly individualized in terms of time to criterion, although all students would go through training in the same order.) This approach of teaching the last part of the overhead pattern first, not only allows the student to experience the immediate reinforcement (a safe landing), but also provides overlearning of that part of the task which is most difficult. When the final can be executed to criterion, the final turn would be added to the chain. Here again, the components of this segment would be presented, via preprogrammed exercises in the simulator, until the student could execute all of them successfully (trimming, slowing airspeed, correcting for wind conditions, etc.). At this point, the student would be positioned just at the beginning of the final turn and would then fly the rest of the pattern. To facilitate the acquisition of these two components, the simulator would be adjusted so that they could be flown initially in slow motion. With each successful execution, the simulator would program faster speeds until normal operational speeds were reached. In addition, an extra wide runway could be provided on the first few tries, and it would gradually be made narrower and narrower on each pass until the normal width was reached. Next, the downwind leg would be added, and so on, working backward, while training the components and adjusting the dimensions of difficulty at each stage.

This approach to teaching a task to a new student could be programmed into an advanced simulator without any additional hardware being required, and although the process may sound lengthy, it would actually take less time than is normally required to learn a task. Furthermore, the backward chain allows a student to gain immediate positive feedback for a correct performance which should contribute to rapid acquisition of the skill.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The purpose of the above discussion has been to lay out the basic framework of the behavior analysis approach and to suggest ways that the principles of behavior might be applied to flying training. Since there is little debate that flying is an acquired skill, one may immediately begin to ask what principles of behavior relate most directly to the acquisition of the repertoire. Clearly there is a great deal of research to be done inasmuch as the foundation has yet to be laid. The following very basic questions have yet to be asked. What teaching techniques does an IP use to improve learning? How best can the functions currently found on most modern simulators be used? How should the "freeze" be used? Should it be used as a time-out or should the student be allowed to initiate the freeze mode to allow a momentary reduction in information overload? When should replay be employed and does it really enhance learning? How might individualized instruction techniques be used to accelerate learning?

In the larger realm of simulator design, not even the simplest questions have yet been considered. What are the effects of automated adaptive instruction on the acquisition of flying skills? How may the components of each task be analyzed, and what is the best sequence for teaching them? How might immediate automatic feedback from the computer be used to enhance learning and increase motivation? What visual aids could be developed to facilitate the acquisition of complex flying repertoires? How are these prompts best faded from the environment? How might the special characteristics of the simulator, such as flying in slow motion, enlarging parts of

the visual scene, and giving control of many operations to the computer, be used to speed up flying training while reducing errors and improving generalization to the aircraft?

The prospect of entering this new era of simulator research is exciting and the payoff to both the field of psychology as well as the Air Force should be great indeed.

REFERENCES

Ayllon, T., & Azrin, N.H. *The token economy: A motivational system for therapy and rehabilitation.* New York: Appleton-Century-Crofts, 1968.

Azrin, N.H., & Holz, W.C. Punishment. In W.L. Honig (Ed.), *Operant behavior: Areas of research and application.* New York: Appleton-Century Crofts, 1966, pp. 380–447.

Baer, D.M., Risley, T.R., & Wolf, M.M. Some current dimensions of applied behavior analysis. *Journal of Applied Behavior Analysis,* 1968, **1**, 91–97.

Bailey, J.S. *A handbook of research method in applied behavior analysis.* New York: Plunem Publishing Company, in press.

Bandura, A. *Principles of behavior modification.* New York: Holt, Rinehart & Winston, 1969.

Bostow, D.E., & Bailey, J.S. Modification of severe disruptive and aggressive behavior using brief timeout and reinforcement procedures. *Journal of Applied Behavior Analysis,* 1969, **2**, 31–38.

Broden, M., Bruce, C., Mitchell, M.A., Carter, V., & Hall, R.V. Effects of teacher attention on attending behavior of two boys at adjacent desks. *Journal of Applied Behavior Analysis,* 1970, **3**, 199–204.

Caro, P.W. *Some factors influencing Air Force simulator training effectiveness.* HumRRO-TR-77-2. Alexandria, Virginia, March 1977. (a)

Caro, P.W. *Some current problems in simulator design, testing, and use.* HumRRO Professional Paper 2-77. Alexandria, Virginia, March 1977. (b)

Committee on Armed Services, U.S. Senate, 94th Congress, 2d Session. *Flight simulators.* Hearing before the subcommittee on research and development. Washington, D.C.: U.S. Government Printing Office, May 1976.

Copeland, R.E., Brown, R.E., & Hall, R.V. The effects of principal-implemented techniques on the behavior of pupils. *Journal of Applied Behavior Analysis,* 1974, **7**, 77–86.

Eddowes, E.E., & King N.W. *Self-perceived problems of student pilots eliminated from undergraduate pilot training.* AFHRL-TR-75-8, AD-A016 417. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, July 1975.

Hagin, W.V., & Smith, J.F. *Advanced simulation in undergraduate pilot training (ASUPT) facility utilization plan.* AFHRL-TR-74-43. AD-786 411. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, June 1974.

Hall, R.V., Lund, D., & Jackson, D. Effects of teacher attention study behavior. *Journal of Applied Behavior Analysis*, 1968, **1**, 1–12.

Hughes, R.G. Enabling features versus instructional features in flying training simulator. In *Proceedings of the 11th NTEC/Industry Conference*, Orlando, Florida, November 1978.

Hughes, R.G. *Advanced training features: Bridging the gap between in-flight and simulator-based models of flying training.* AFHRL-TR-78-96, AD-A068 142. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, March 1979.

Hughes, R.G., Paulsen, J.G., Brooks, R.B., & Jones, W.E. Visual cue manipulation on air-to-surface weapons delivery task. *Proceedings of the 11th NTEC Industry Conference*, Orlando, Florida, November 1978.

Isley, R.N., & Miller, E.J. *The role of automated training in future Army simulators.* HumRRO-FR-ED-76-27. Pensacola, FL: Human Resources Research Organization, October 1976.

Iwata, B.A., Bailey, J.S., Brown, K.M., Foshee, T.J., & Alpern, M. A performance-based lottery to improve residential care and training by institutional staff. *Journal of Applied Behavior Analysis*, 1976, **9**, 417–432.

Johnson, M., & Bailey, J.S. Cross-age tutoring: Fifth graders as arithmetic tutors for kindergarten children. *Journal of Applied Behavior Analysis*, 1974, **7**, 223–232.

Kazdin, A.E. *Behavior modification in applied settings.* Homewood, IL: The Dorsey Press. 1975.

Kazdin, A.E. *History of behavior modification.* Baltimore: University Park Press, 1978.

Keller, F.S. Goodbye teacher... *Journal of Applied Behavior Analysis*, 1968, **1**, 79–90.

Kron, G.J. *Advanced simulation in undergraduate pilot training: Motion system development.* AFHRL-TR-75-59(II), AD-A017 467. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, October 1975. (a)

Kron, G.J. *Advanced simulation in undergraduate pilot training: G-seat development.* AFHRL-TR-75-59(III), AD-A017 468. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, October 1975. (b)

Martin, E.L., & Waag, W.L. *Contributions of platform motion to simulator training effectiveness: Study I – Basic contact.* AFHRL-TR-78-15, AD-A058 416. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, June 1978.

Martin, G., & Pear, J. *Behavior modification: What it is and how to do it.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1978.

Meyer, R.P., Laveson, J.I., Weissman, N.S., & Eddowes, E.E. *Behavioral taxonomy of undergraduate pilot training tasks and skills: Executive summary.* AFHRL-TR-74-33(I), AD-A008 771. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, December 1974.

Miller, L.K., & Weaver, F.H. A behavioral technology for producing concept formation in university students. *Journal of Applied Behavior Analysis*, 1976, **9**, 289–300.

Nass, L., Seats, P., & Albery, W. *Advanced simulation in undergraduate pilot training: Visual display development.* AFHRL-TR-75-59(VI), AD-A022 962. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, December 1975.

Perry, R.A. Personal communication, 1978.

Prather, D. Personal communication, 1978.

Risley, T.R. Behavior modification: An experimental-therapeutic endeavor. In L.A. Hammerlynck, P.O. Davidson, & L.E. Acker (Eds.), *Behavior modification and ideal mental health services.* Calgary, Canada: University of Calgary Press, pp. 103–127.

Skinner, B.F. *Science and Human Behavior.* New York: Free Press, 1953.

Skinner, B.F. *The technology of teaching.* New York: Appleton-Century-Crofts, 1968.

Skinner, B.F. *Contingencies of reinforcement: A theoretical analysis.* New York: Appleton-Century-Crofts, 1969.
Appleton-Century-Crofts, 1969.

Smith, B.A., Waters, B.K., & Edwards, B.J. *Cognitive pretraining of the T-37 overhead traffic pattern.* AFHRL-TR-75-72, AD-A026 118. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, December 1975.

Van Houten, R., & Sullivan, K. Effects of an audio cueing system on the rate of teacher priase. *Journal of Applied Behavior Analysis*, 1975, **8**, 197–202.

Waag, W.L., Eddowes, E.E., Fuller, J.H., & Fuller, R.R. *ASUPT automated objective performance measurement system.* AFHRL-TR-75-3, AD-A014 799. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, March 1975.